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Learning Ocean Science through Ocean Exploration

Section 3
Currents

Currents Are an Important Consideration

Each time a submersible goes down on an Ocean Exploration expedition, currents are an important consideration. If it is tethered, as are ROVs, not only will the current tug at the ROV, but it will also pull at the entire length of the tether. An autonomous submersible may be forced into a position from which it cannot free itself with its relatively weak thrusters, endangering lives as well as equipment. Additionally, the surface currents may be very different than currents at depth.

Surface currents are generated largely by wind. Their patterns are determined by wind direction, Coriolis forces from the Earth's rotation, and the position of landforms that interact with the currents. Surface wind-driven currents generate upwelling currents in conjunction with landforms, creating deepwater currents.

Currents may also be generated by density differences in water masses caused by temperature and salinity variations. These currents move water masses through the deep ocean—taking nutrients, oxygen and temperature with them.

Occasional events also trigger serious currents. Huge storms move water masses. Underwater earthquakes may trigger devastating tsunamis. Both move masses of water inland when they reach shallow water and coastlines. Earthquakes may also trigger rapid downslope movement of water-saturated sediments, creating turbidity currents strong enough to snap submarine communication cables. Bottom currents scour and sort sediments, thus affecting what kind of bottom develops in an area—hard or soft, fine grained or coarse. Bottom substrate determines what kinds of communities may develop there.

Understanding Currents Is Critical to the Success of Ocean Exploration Expeditions

Finally, when a current that is moving over a broad area is forced into a confined space, it may become very strong. On the ocean floor, water masses forced through narrow openings in a ridge system or flowing around a seamount may create currents that are far greater than in the surrounding water—affecting both the distribution and abundance of organisms as well as the scientists and their equipment seeking to study them. Consequently, understanding currents and their patterns at a site is critical to the success of an Ocean Exploration expedition. There are three excellent current activities on the OE CD. One is modified and presented here, but you may wish to look at all three:

Where to Find More Activities on Currents

- *Current Events* in the Arctic Ocean Exploration 2002 examines density driven currents
- *In Gyre Straits* from Islands in the Stream 2002 looks at forces that create a gyre off of the Gulf Stream
- *Currents: Bad for Divers; Good for Corals* in the Northwest Hawaiian Islands Exploration 2002 examines the interaction between landforms and currents; it has been modified for this publication as it has general application to the OE expeditions.

Lesson Plan 5

Speeding Up: Deep Currents and Landforms

Focus
Deep-sea currents

Focus Question
How are deep-sea currents affected by submarine topography?

Learning Objectives
Students will examine the general effects of topography on deepwater ocean current speed.

Students will examine and discuss how speed affects the ability of a current to transport sediment or sand.

Students will apply information from the demonstrations to the problem of working in underwater submersibles around undersea landforms.

Materials
- ❒ Plastic flower window box (light-colored or spray painted white inside - about 30cm wide by 1m long by 20cm deep
- ❒ Sink with small diameter hose attached to faucet or 5-gallon capacity container with a siphon and flow-control clamp
- ❒ Rubber or plastic tubing about 1/2-in in diameter
- ❒ Cork or rubber stopper same size a hole in box
- ❒ Drill bit and drill with diameter that matches the tubing
- ❒ Silicone aquarium cement
- ❒ Large plastic eye dropper or pipette
- ❒ Two adjustable hose clamps
- ❒ Dye solution: 20 drops food coloring or India ink in 250 ml water
- ❒ Two or three blocks of modeling clay per student group
- ❒ Mixed sand (collected from several locations on a beach or builders' sand from builders supply store, about 150 ml per group

Teaching Time
Two 45-minute class periods

Seating Arrangement
Groups of four to six students

Key Words
Seamount
Mid-Atlantic ridge
Submarine canyon
Reef
Bank
Currents

Background Information
This activity focuses on topographic effects on deepwater currents and on how these currents may affect bottom characteristics that in turn influence species composition of an area. They may also affect the scientists studying an area. During the Ocean Exploration expedition to the Northwest Hawaiian Islands on September 22, 2002, the deep-diving submersible Pisces IV was pinned against an underwater cliff by a strong current 1,465 ft below the surface. After some tense moments, the submersible's pilot was able to break free (read more at http://oceanexplorer.noaa.gov/explorations/02hawaii/logs/sep22/sep22.html). Scientists believe that these strong currents may have an important role in shaping the deep-sea habitat around the Northwestern Hawaiian Islands.

Underwater currents shape both the bottom characteristics by sorting sediments and scouring hard bottom. The species composition of an area is determined in part by these features.

While surface currents are directly influenced by the frictional drag of wind moving over the ocean surface, purely wind-driven currents do not penetrate much below 100 m. In deeper water, currents are driven by pressure gradients which are a function of density and water depth. Changes in seawater density are caused by changes in salinity and/or temperature. Although it seems as if water depth in a given location is uniform, this is not always true. Even without wind, the sea's surface is not absolutely flat, but rather has broad mounds and valleys. Even small pressure gradients cause water to flow from regions of high pressure to low pressure, resulting in barotropic currents. These currents are relatively slow-moving in the open ocean, but can be significantly accelerated near the bottom or around solid objects, like seamounts, ridges or submarine canyons.

Learning Procedure

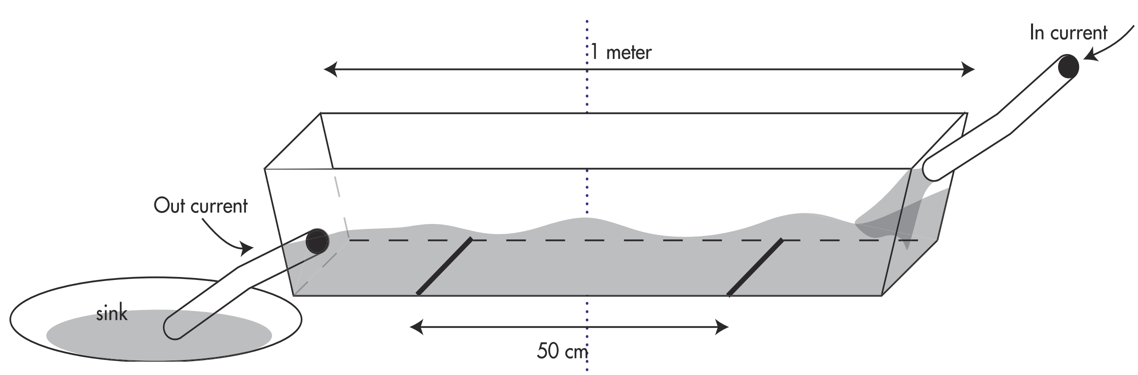
1. Build the current chute by filling the bottom holes in the window box if there are any. Drill holes on the vertical ends as shown below. They should be the same diameter as the tubing on the sink faucet or siphon. Insert the faucet tubing in the high end and seal. Add tubing to the low end and set it over the sink to catch the overflow. Attach hose clamps to each tube. Use a waterproof marker to make a 50 cm current racecourse in the center of the box, marking the front and back ends. See illustration for design. It is a bit time consuming to make this, but it can be used repeatedly. Modeling clay does not perform well when repeatedly soaked, but can be used more than once if handled carefully and not left in water very long.

2. With students, review the major forces that drive ocean currents discussed in the introduction above. Be sure students distinguish between currents that are largely wind-driven (less than 100 m deep) and those that result from pressure gradients due to differential density and/or depth. Students may read the log entries of September 22 (web address above) to get a sense of the force of deepsea currents.

3. How do scientists study currents in the lab? Ask for ideas. They actually build test tanks that simulate conditions in the ocean and study waves and currents in models of the real world. Display your test tank.

4. Review the undersea features that were introduced in Section 2 of this curriculum: Seamounts, Mid-Atlantic Ridges, Banks, and Submarine Canyons. Challenge your students to make models of these features to test in your underwater current testing box. Assign each group one of the five geologic features listed above. Explain that they will be

Current Chute



making observations on the effects of these features on current flow. These should be designed as follows, using modeling clay:

a. **Bank #1**: a flat round surface, like a pancake, about 10 cm diameter and 2 cm high.
b. **Bank #2 or Reef**: a low rounded form like half of a hardboiled egg about 10 cm long, 5 cm at its highest point and 5 cm at its widest point; rocky outcrops are referred to as reefs by mariners.
c. **Seamount**: a cone-shaped mountain that is 6-8 cm high and 10 cm across at the base.
d. **Mid-Atlantic Ridge**: a ridge of clay that spans the entire width of the test tank that is 6 cm high, 6 cm wide and as long as the tank is wide; cut two notches in the ridge—one 5 cm deep and the other 2 cm deep.
e. **Submarine Canyon**: collect spare clay from other groups and make a platform that fills the box from side to side in the middle and is about 5-6 cm high; carve a canyon in it with the shallow end on the side with the incoming current and the deepest end all the way to the bottom of the test tank on the outflow end; there many be twists in the canyon if desired.

5. To study the effects of the models on current flows:
   a. Set up the tank at the sink and test its function before class; empty it.
   b. Place a model in the test tank nearer the inflow end with object just touching the upstream start of the 50-cm range markings.
   a. Fill the window box about 3/4 full of water. Adjust the clamp on the siphon tubing so that water is flowing into one end at about 500 ml per minute.
   c. Adjust the outflow to match input when the box is ¾ full.
   d. Fill a pipette or long eye dropper about half full with dye solution. Being careful not to squeeze the rubber bulb, place the tip of the pipette just above the model surface at the end of the 50-cm mark. Gently squeeze a small amount of dye solution out of the pipette, and measure the time required for the dye plume to reach the other end of the 50-cm interval mark. Repeat this procedure by placing the tip of the pipette at the end of the model nearest the inflow from the siphon. Repeat these steps twice more, and calculate the average flow rate in cm per second.
   e. Repeat for each model.

6. Then test the model for current effect on sediment before switching to the next model. Pour about 50 ml of mixed sand into the top end of the test tank and record observations.

7. Increase the flow rate to about 1,000 ml per minute and repeat sediment test. Record student observations.

8. Clean test tank and repeat with the next model.

9. Have groups present their results. Lead a discussion to analyze these results. Students should have observed that current flow is increased around steep objects or objects that confine the water flow to a narrow passage. This flow acceleration can cause large, slow flowing water masses to become extremely strong and rapid currents. Students should also have observed that smaller particles of sand tend to be carried farther by currents than larger particles and that when speed of the current increases, the particle-carrying capacity of the current also increases.

10. What happened to sediment landing on the models? It was scoured by the current where currents moved fastest. What characteristics would be required of organisms growing on these sites? Species that are sediment aversive, species that have strong attachments, species that depend on currents to bring food—all might grow here. How might current influence on the distribution and sorting of sediments by particle size affect species composition of a soft bottom area?

The BRIDGE Connection

www.vims.edu/bridge.html

The "Me" Connection

Tell students to imagine that they are visitors to one of the uninhabited Northwestern Hawaiian Islands. Have them write a short essay on what signs they might look for in potential swimming areas that could indicate the presence of dangerously-strong currents.

Connections To Other Subjects

English/Language Arts, Physics, Biology, Mathematics

Evaluation

Develop a grading rubric that includes skill in laboratory observations and participation in discussions. You may wish to have students prepare individual written analyses prior to group discussion.

Extensions

Visit http://topex-www.jpl.nasa.gov/ for lots of information, links, and activities related to sea surface monitoring by satellites, El Niño, and other oceanography topics.

Resources

http://oceanexplorer.noaa.gov – the Northwestern Hawaiian Islands Expedition documentaries and discoveries are posted.

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Motion and forces

Content Standard D: Earth and Space Science

- Energy in the Earth system

Activity developed by Mel Goodwin, PhD, The Harmony Project, Charleston, SC